Optoelectronic spin control in semiconductor nanostructures

D.D. Awschalom, *University of California – Santa Barbara, DMR-0305223*
N. Samarth, *Pennsylvania State University, DMR-0305238*

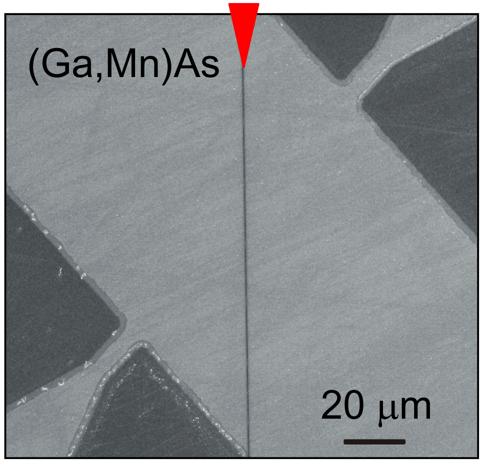
- Developed new techniques for patterning and imaging *nuclear spins* in semiconductors for information processing at the subatomic level.

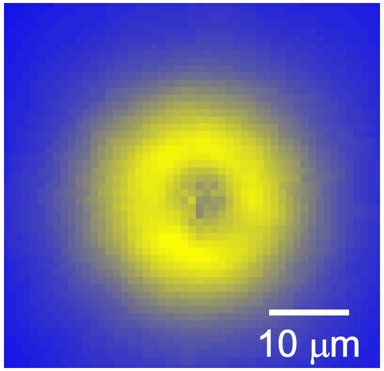
- Demonstrated electrical control of single domain walls in ferromagnetic semiconductor devices for submicron storage.

- Fabricated and measured electrically tunable terahertz spin coherence in nanometer-scale magnetic heterostructures for ultrahigh frequency spintronics.

- *Appl. Phys. Lett., in press (2004)*
- *Nature, in press (2004)*.

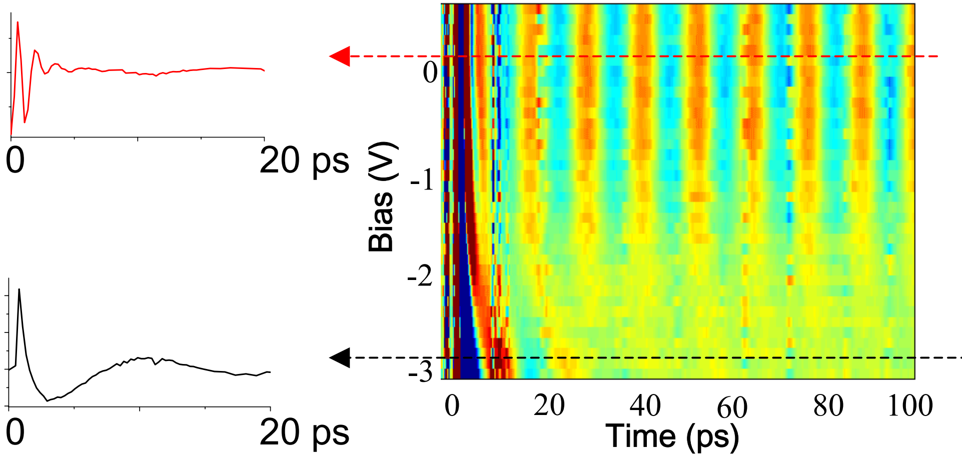
Trapping single domains





Nuclear "doughnuts"

THz spin precession



Three new developments are shown in this slide:

The ability to pattern nuclear spins and their polarization with optics. The example shown is an image of polarized nuclear spins in GaAs (Ga-79 nuclei) that have been patterned into a ring. In this case, a polarized light pulse creates spin-polarized electrons that rapidly spread radially from the center, stop, and subsequently transfer their spins to nuclear moments. The image is taken using a low-temperature spatio-temporal optical scanning probe system built for the research effort, with 150 femtosecond time resolution and 1 micron spatial resolution.

We have grown ferromagnetic GaMnAs using MBE techniques, and fabricated miniature Hall bars out of the material. With the use of a focused ion beam and a standard commercial process, pinning sites can be arbitrarily placed on the device, and used to trap single domain walls in the system. Once trapped, we are able to perform transport studies of electrons moving through a single wall – the first measurements of this kind.

3) The third example results from the ability to fabricate (using MBE) parabolic quantum wells with magnetic dopants that can be electrically gated. The presence of the magnetic atoms dramatically increases the natural g-factor of the electron, moving the electron spin frequency toward the terahertz regime. The precession frequency can be tuned with a few volts from almost zero to about 1 THz, thus demonstrating the potential for on-chip terahertz electronics that is integreable with on-chip magnetics.

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Education:

Undergraduates:
Julian Davis (M)
Maiken Mikkelsen (F)
Billie Rolih (F)

Graduate students:
Jesse Berezovsky
Jason Stephens
Roberto Myers
Keh Chiang Ku
Xia Li
William Fadgen

Postdoctoral student:
Alex Holleitner
(also California NanoSystems Institute Fellow)

Outreach:

Undergraduate summer intern programs including community colleges.

Societal Impact:

The research offers new pathways towards extremely high density storage and future quantum information processing at the subatomic level, ranging from nuclear computation, domain wall memories, and terahertz electronics for imaging and communication.

These efforts may help meet the strong demands for improved technologies in communication and computation.